APPENDIX E

NOISE AND ITS EFFECT ON PEOPLE AND NOISE MODELING TECHNICAL REPORT

Index

E.1

Noise and Its Effect on People

NOISE AND ITS EFFECT ON PEOPLE

This section includes a general overview of noise and its metrics and provides a description of the effect noise, in particular aircraft noise, has on people.

NOISE AND ITS EFFECT ON PEOPLE

Aircraft noise exposure in this document is primarily addressed using the Day-Night Average Sound Level (DNL) metric. This study also involves the use of supplemental noise metrics in addition to DNL to provide comprehensive analysis for quantifying a specific situation. To assist reviewers in interpreting complex noise metrics, this appendix presents an introduction to the relevant fundamentals of acoustics and noise terminology and the effects of noise on human activity.

NOISE AND ITS METRICS

Noise, often defined as unwanted sound, is one of the most common environmental issues associated with aircraft operations. Of course, aircraft are not the only sources of noise in an urban or suburban surrounding, where interstate and local roadway traffic, rail, industrial, and neighborhood sources may also intrude on the everyday quality of life. Nevertheless, aircraft are readily identifiable to those affected by their noise and are typically singled out for criticism. Consequently, aircraft noise problems often dominate analyses of environmental impacts.

A “metric” is defined as something “of, involving, or used in measurement.” As used in environmental noise analyses, a metric refers to the unit or quantity that quantitatively measures the effect of noise on the environment. Noise studies have typically involved a confusing proliferation of noise metrics used by individual researchers who have attempted to understand and represent the effects of noise. As a result, literature describing environmental noise or environmental noise abatement has included many different metrics.

Recently, however, various federal agencies involved in environmental noise mitigation have agreed on common metrics for environmental impact analysis documents. Furthermore, the FAA has specified which metrics, such as DNL, should be used for federal aviation noise assessments.

This section discusses the following acoustic terms and metrics:

- Decibel, dB
- A-Weighted Decibel, dBA
- Maximum Sound Level, L_{max}
- Sound Exposure Level, SEL
- Equivalent Sound Level, L_{eq}
- Day-Night Average Sound Level, DNL
- Time-Above a Specified Level, TA

The Decibel, dB

All sounds come from a sound source—a musical instrument, a speaking voice, or an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source is transmitted through the air in sound waves—tiny, quick oscillations of pressure just above and just below atmospheric pressure. These oscillations, or sound pressures, impinge on the ear, creating the sound we hear.

Our ears are sensitive to a wide range of sound pressures. The loudest sound that we hear without pain has about one trillion times more energy than the quietest sounds we hear. As this range, on a linear scale, is unwieldy, we compress the total range of sound pressures to a more meaningful range by introducing the concept of sound pressure level (SPL) and its logarithmic unit of decibel (dB).

SPL is a measure of the sound pressure of a given noise source relative to a standard reference value (typically the quietest sound that a young person with good hearing can detect). Decibels are logarithmic quantities—logarithms of the ratio of the two pressures, the numerator being the pressure of the sound source of interest, and the denominator being the reference pressure (the quietest sound we can hear).

The logarithmic conversion of sound pressure to SPL means that the quietest sound we can hear (the reference pressure) has a SPL of about zero decibels, while the loudest sounds we hear without pain have SPLs less than or equal to about 120 dB. Most sounds in our day-to-day environment have SPLs from 30 to 100 dB.

Because decibels are logarithmic quantities, they require logarithmic math and not simple (linear) addition and subtraction. For example, if two sound sources each produce 100 dB and are operated together, they produce only 103 dB—not 200 dB as might be expected. Four equal sources operating simultaneously result in a total SPL of 106 dB. In fact, for every doubling of the number of equal sources, the SPL (of all of the sources combined) increases another three decibels. A ten-fold increase in the number of sources makes the SPL increase by 10 dB. A hundredfold increase makes the level increase by 20 dB, and it takes a thousand equal sources to increase the level by 30 dB.

If one source is much louder than another, the two sources together will produce the same SPL (and sound to our ears) as if the louder source were operating alone. For example, a 100 dB source plus an 80 dB source produce 100 dB when operating together. The louder source "masks" the quieter one. But if the quieter source gets louder, it will have an increasing effect on the total SPL. When the two sources are equal, as described above, they produce a level 3 decibels above the sound level of either one by itself.

From these basic concepts, note that one hundred 80 dB sources will produce a combined level of 100 dB; if a single 100 dB source is added, the group will produce a total SPL of 103 dB. Clearly, the loudest source has the greatest effect on the total.

There are two useful rules of thumb to remember when comparing SPLs: (1) most of us perceive a 6 to 10 dB increase in the SPL to be an approximate doubling of loudness, and (2) changes in SPL of less than about 3 dB are not readily detectable outside of a laboratory environment.

A-Weighted Decibel, dBA

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of the sound pressure oscillations as they reach our ear. Frequency can be expressed in units of cycles per second (cps) or Hertz (Hz). Although cps and Hz are equivalent, Hz is the preferred scientific unit and terminology.

A very good ear can hear sounds with frequencies from 16 Hz to 20,000 Hz. However, most people hear from approximately 20 Hz to approximately 10,000-15,000 Hz. People respond to sound most readily when the predominant frequency is in the range of normal conversation, around 1,000 to 4,000 Hz. Acousticians have developed and applied "filters" or "weightings" to SPLs to match our ears' sensitivity to the pitch of sounds and to help us judge the relative loudness of sounds made up of different frequencies. Two such filters, "A" and "C," are most applicable to environmental noises.

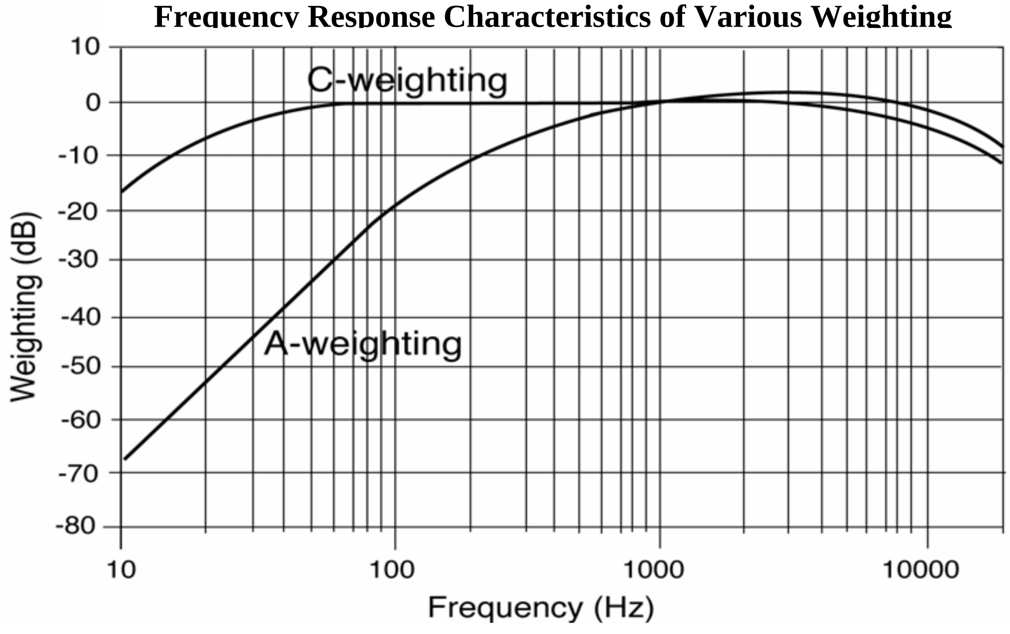
A-weighting significantly de-emphasizes noise at low and high frequencies (below approximately 500 Hz and above approximately 10,000 Hz) where we do not hear as well. The filter has little or no effect at intervening frequencies where our hearing is most efficient. **Figure E-1** shows a graph of the A-weighting as a function of frequency and its aforementioned characteristics. Because this filter generally matches our ears' sensitivity, sounds having higher A-weighted sound levels are usually judged to be louder than those with lower A-weighted sound levels, a relationship which does not always hold true for unweighted levels. Therefore, A-weighted sound levels are normally used to evaluate environmental noise. SPLs measured through this filter are referred to as A-weighted decibels (dBA).

As shown in Figure E-1, C-weighting is nearly flat throughout the audible frequency range, hardly de-emphasizing the low frequency noise. C-weighted levels are not used as frequently as A-weighted levels, but they may be preferable in evaluating sounds whose low-frequency components are responsible for secondary effects such as the shaking of a building, window rattle, perceptible vibrations, or other factors that can cause annoyance and complaints. Uses include the evaluation of blasting noise, artillery fire, sonic boom, and, in some cases, aircraft noise inside buildings. SPLs measured through this filter are referred to as C-weighted decibels (dBC).

Other weighting networks have been developed to correspond to the sensitivity and perception of other types of sounds, such as the "B" and "D" filters. However, A-weighting has been adopted as the basic measure of community environmental noise by the U.S. Environmental Protection Agency (EPA) and nearly every other agency concerned with aircraft noise throughout the United States.

Figure E-1

Frequency Response Characteristics of Various Weighting



Source: ANSI S1.4-1983 "Specification of Sound Level Meters"

Figure E-2 presents typical A-weighted sound levels of several common environmental sources. Sound levels measured (or computed) using A-weighting are most properly called "A-weighted sound levels" while sound levels measured without any frequency weighting are most properly called "sound levels." However, since this document deals only with A-weighted sound levels, the adjective "A-weighted" will be hereafter omitted, with A-weighted sound levels referred to simply as sound levels. As long as the use of A-weighting is understood, there is no difference implied by the terms "sound level" and "A-weighted sound level" or by the dB or dBA units.

An additional dimension to environmental noise is that sound levels vary with time and typically have a limited duration, as shown in **Figure E-3.** For example, the sound level increases as an aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance (although even the background varies as birds chirp, the wind blows, or a vehicle passes by). Sounds can be classified by their duration as continuous like a waterfall, impulsive like a firecracker or sonic boom or intermittent like an aircraft overflight or vehicle passby.

Maximum Sound Level, L_{max}

The variation in sound level over time often makes it convenient to describe a particular noise "event" by its maximum sound level, abbreviated as L_{max}. For the aircraft over-flight event in Figure E-3, the L_{max} is approximately 67 dBA.

Figure E-4 shows L_{max} values for a variety of common aircraft from the FAA's Integrated Noise Model database. These L_{max} values for each aircraft type are for aircraft performing a maximum stage (trip) length departure on a day with standard atmospheric conditions at a reference distance of 3.5 nautical miles from their brake release point. Of the dozen aircraft types listed on the figure, the Concorde has the highest L_{max} and the Saab 340 (SF340) has the lowest L_{max}.

The maximum level describes only one dimension of an event; it provides no information on the cumulative noise exposure generated by a sound source. In fact, two events with identical maxima may produce very different total exposures. One may be of short duration, while the other may continue for an extended period. The metric, discussed later in this appendix, corrects for this deficiency.

Sound Exposure Level, SEL

A frequently used metric of noise exposure for a single aircraft flyover is the Sound Exposure Level, or SEL. SEL may be considered an accumulation of the sound energy over the duration of an event. The shaded area in **Figure E-5** illustrates that portion of the sound energy (or "dose") included in an SEL computation. The dose is then normalized (standardized) to a duration of one second. This "revised" dose is the SEL, shown as the shaded rectangular area in Figure E-5. Mathematically, the SEL represents the sound level of the constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For events that last more than one second, SEL does not directly represent the sound level heard at any given time, but rather provides a measure of the net impact of the entire acoustic event.

Figure E-2

Sound Levels of Typical Noise Sources (dBA)

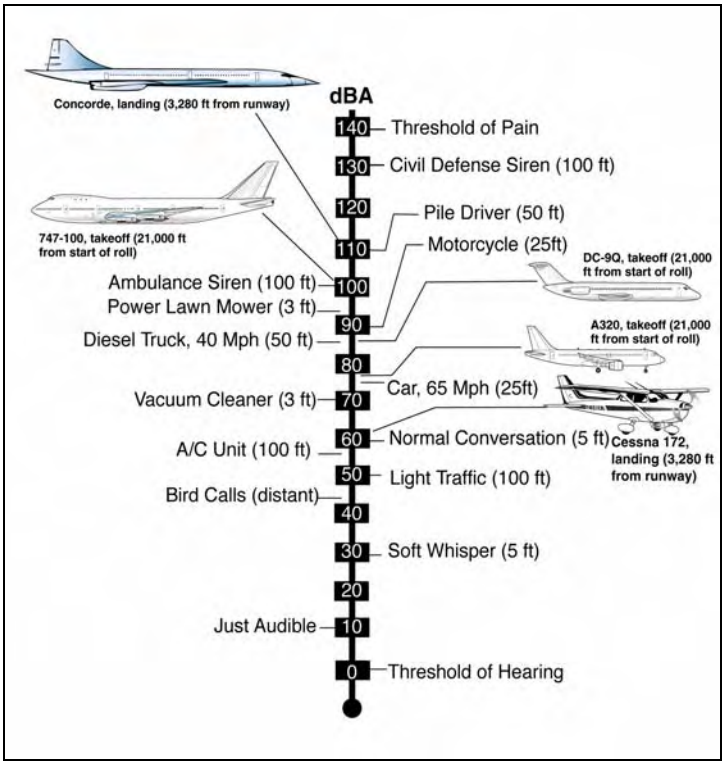
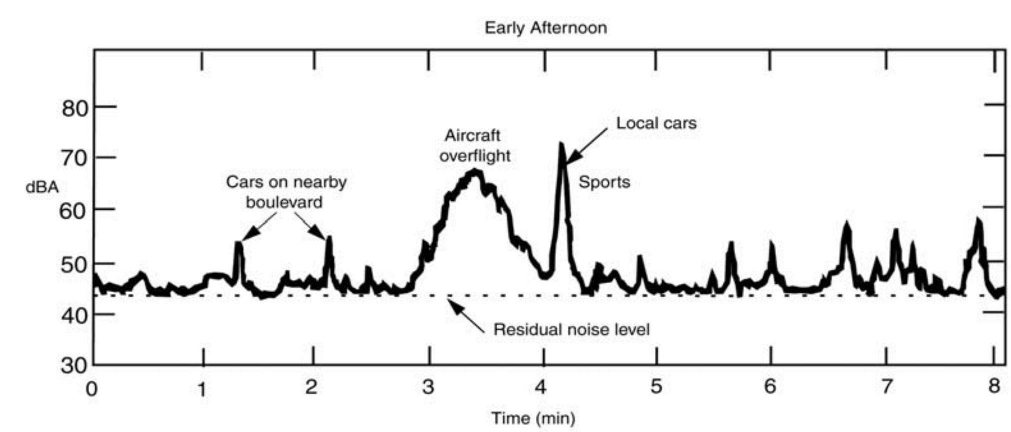


Figure E-3

Variation of Community Noise in a Suburban Neighborhood



Source: "Community Noise," NTID 300.3 EPA, December 1971.

Figure E-4

Common Aircraft Departure Noise Levels

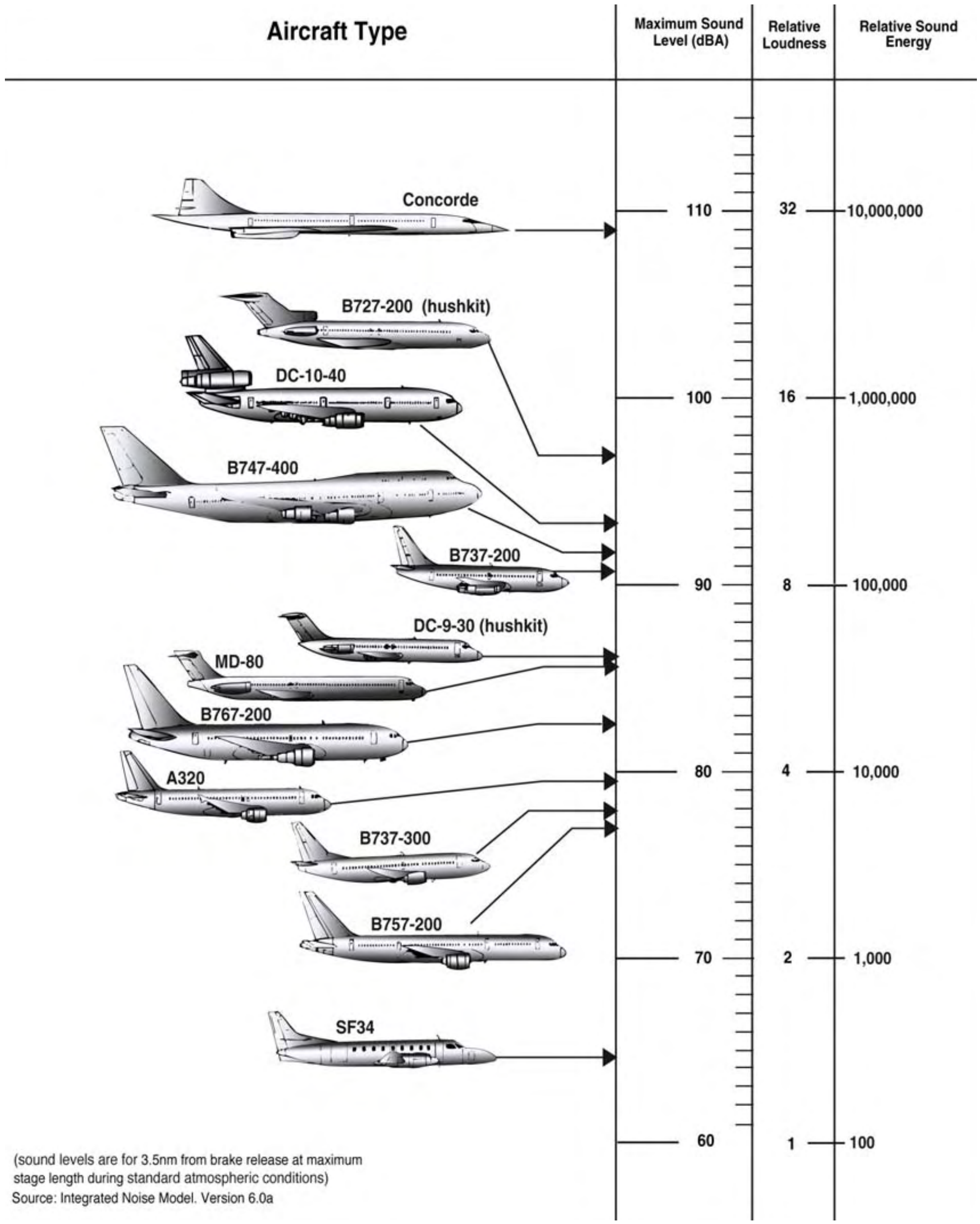
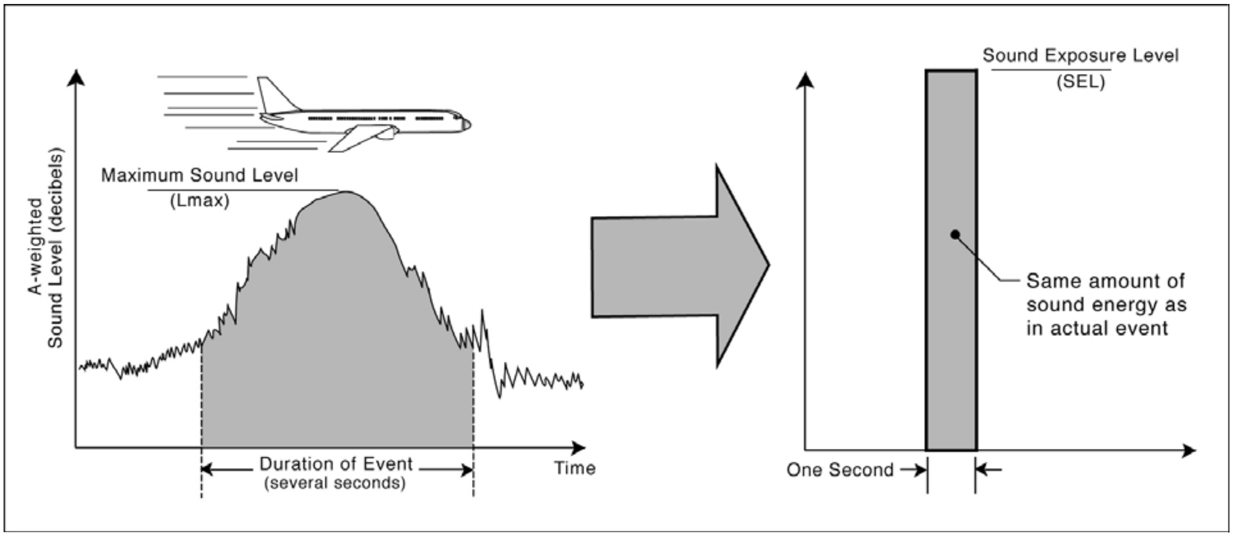


Figure E-5

Relationship Between Single Event Noise Metrics



Note that, because the SEL is normalized to one second, it will always be larger in magnitude than the maximum A-weighted level for an event that lasts longer than one second. In fact, for most aircraft overflights, the SEL is on the order of 7 to 12 dBA higher than the L_{max}. The fact that it is a cumulative measure means that not only do louder flyovers have higher SELs than quieter ones (of the same duration), but longer flyovers also have greater SELs than shorter ones (of the same L_{max}).

It is the SEL's inclusion of both the intensity and duration of a sound source that makes SEL the metric of choice for comparing the single-event levels of varying duration and maximum sound level. This metric provides a comprehensive basis for modeling a noise event in determining overall noise exposure.

Equivalent Sound Level, L_{eq}

Maximum A-weighted level and SEL are used to measure the noise associated with individual events. The following metrics apply to longer-term cumulative noise exposure that often includes many events.

The first cumulative noise metric, the Equivalent Sound Level (abbreviated L_{eq}), is a measure of the exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest (e.g., an hour, an 8-hour school day, nighttime, or a full 24-hour day). However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example $L_{eq(8)}$ or $L_{eq(24)}$.

As for its application to aircraft noise issues, L_{eq} is often presented for consecutive 1-hour periods to illustrate how the hourly noise dose rises and falls throughout a 24-hour period, as well as how certain hours are significantly affected by a few loud aircraft. Since the period of interest for this study is in a full 24-hour day, $L_{eq(24)}$ is the proper nomenclature.

Conceptually, L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level with its normal "peaks" and "valleys," as illustrated in Figure E-3. In the context of noise from typical aircraft flight events and as noted earlier for SEL, L_{eq} does not represent the sound level heard at any particular time, but rather represents the total sound exposure for the period of interest. Also, it should be noted that the "average" sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or "energy-averaged," sound level. Thus, loud events tend to dominate the noise environment described by the L_{eq} metric.

Day-Night Average Sound Level

DNL is the same as L_{eq} (an energy-average noise level over a 24-hour period) except that 10 dB is added to those noise events occurring at night (between 10 p.m. and 7 a.m.). This weighting reflects the added intrusiveness of nighttime noise events attributable to the fact that community back-ground noise levels typically decrease by about 10 dB during those nighttime hours. DNL does not represent the sound level heard at any particular time, but rather represents the total (and partially weighted) sound exposure.

Typical DNL values for a variety of noise environments are shown in **Figure E-6** to indicate the range of noise exposure levels usually encountered.

Due to the DNL metric's excellent correlation with the degree of community annoyance from aircraft noise, DNL has been formally adopted by most federal agencies for measuring and evaluating aircraft noise for land use planning and noise impact assessment. Federal interagency committees such as the Federal Interagency Committee on Urban Noise (FICUN) and the Federal Interagency Committee on Noise (FICON) which include the EPA, FAA, Department of Defense, Department of Housing and Urban Development (HUD), and Veterans Administration, found DNL to be the best metric for land use planning. They also found no new cumulative sound descriptors or metrics of sufficient scientific standing to substitute for DNL. Other cumulative metrics could be used only to supplement, not replace DNL. Furthermore, FAA Order 1050.1E for environmental studies, <u>requires</u> that DNL be used in describing cumulative noise exposure and in identifying aircraft noise/land use compatibility issues.[1 2 3 4 5]

Measurements of DNL are practical only for obtaining values for a relatively limited number of points. Instead, many noise studies, including this document, are based on estimates of DNL using a FAA-approved computer-based noise model.

Time-Above a Specified Level

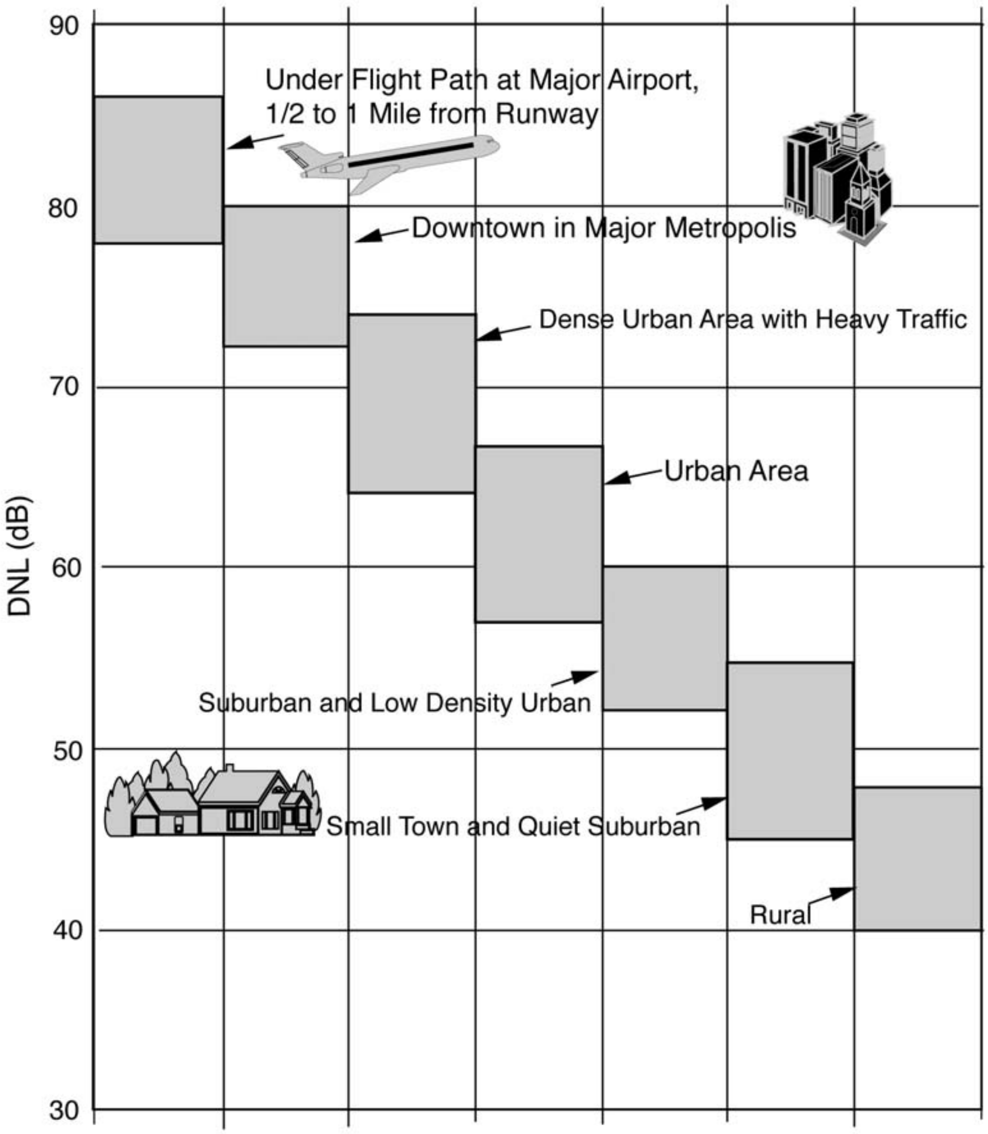
The Time-Above a Specified Level (TA) metric describes the total number of minutes that instantaneous sound levels (usually from aircraft) are above a given threshold. For example, if 65 dB is the specified threshold, the metric would be referred to as "TA65." Like DNL, the TA metric is typically associated with a 24-hour annual average day or only for the DNL nighttime period of 10 p.m. to 7 a.m.

When the TA calculation is expressed as a percentage of the day it is referred to as "%TA." Although the threshold chosen for the TA calculation is arbitrary, it is usually the ambient level for the location of interest or 65 dB for comparison to a level of 65 dB DNL.

For this study, the threshold is 65 dB for the full 24-hour day.

Figure E-6

Typical Range of Outdoor Community Day-Night Average Sound Levels



Source: U.S. Department of Defense. Departments of the Air Force, the Army, and the Navy, 1978. *Planning in the Noise Environment*. AFM 19-10. TM 5-803-2, and NAVFAC P-970. Washington, D.C.: U.S. DoD.

THE EFFECTS OF AIRCRAFT NOISE ON PEOPLE

To many people, aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics aids in the understanding of how and why people react to their environment. This section addresses three ways we are potentially affected by aircraft noise: annoyance, interference of speech, and disturbance of sleep.

Community Annoyance

The primary potential effect of aircraft noise on exposed communities is one of annoyance. The U.S. EPA defines noise annoyance as any negative subjective reaction on the part of an individual or group.[1]

Scientific studies [1 2 3 6 7] and a large number of social/attitudinal surveys[8 9] have been conducted to appraise the U.S. and international community of annoyance due to all types of environmental noise, especially aircraft events. These studies and surveys have found the DNL to be the best measure of that annoyance.

This relation between community annoyance and time-average sound level has been confirmed, even for infrequent aircraft noise events.[10] For helicopter overflights occurring at a rate of 1 to 52 per day, the stated reactions of community individuals correlated with the daily time-average sound levels of the helicopter overflights.

The relationship between annoyance and DNL that has been determined by the scientific community and endorsed by many federal agencies, including the FAA, is shown in **Figure E-7**. Two lines in Figure E-7 represent two large sets of social/ attitudinal surveys: one for a curve fit of 161 data points compiled by an individual researcher, Ted Schultz, in 1978[8] and one for a curve fit of 400 data points (which include Schultz's 161 points) compiled in 1992 by the U.S. Air Force.[11] The agreement of these two curves simply means that when one combines the more recent studies with the early landmark surveys in 1978, the results of the early surveys (i.e., the quantified effect of noise on annoyance) are confirmed.

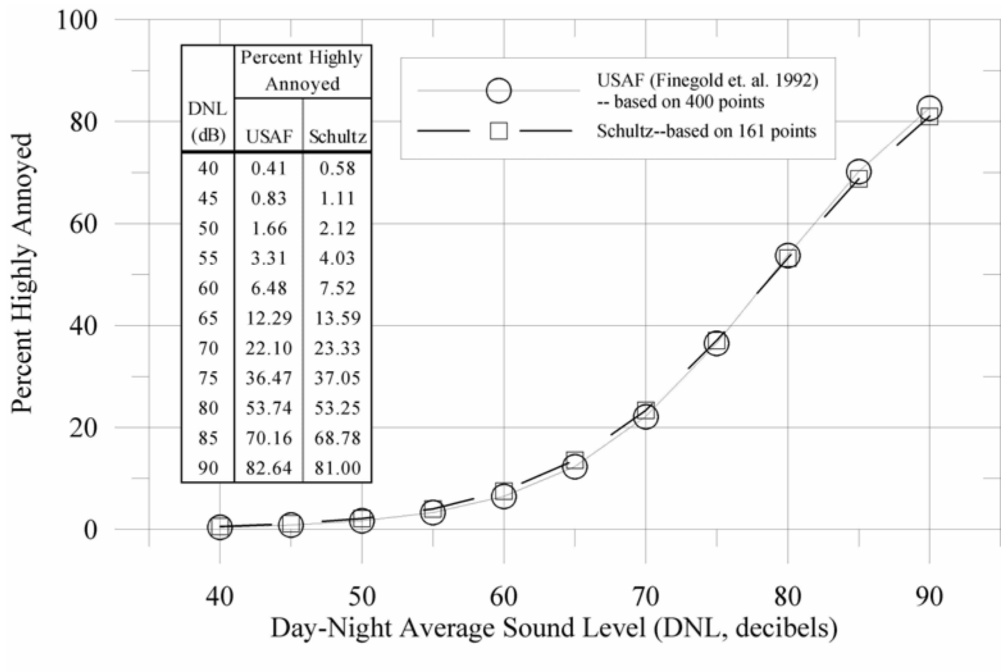
Figure E-7 shows the percentage of people "highly annoyed" by a given DNL. For example, the two curves in the figure yield a value of about 13% for the percentage of the people that would be highly annoyed by a DNL exposure of 65 dB. The figure also shows that at very low values of DNL, such as 45 dB or less, 1% or less of the exposed population would be highly annoyed. Furthermore, at very high values of DNL, such as 90 dB, more than 80% of the exposed population would be highly annoyed.

Recently, the use of DNL has been criticized as not accurately representing community annoyance and land-use compatibility with aircraft noise. One frequent criticism is based on the inherent feeling that people react more to single noise events and not as much to "meaningless" time-average sound levels. In fact, a time-average noise metric, such as DNL, takes into account both the noise levels of all individual events which occur during a 24-hour period and the number of times those events occur. As described briefly above, the logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average.

As a simple example of this characteristic, consider a case in which only one aircraft overflight occurs in daytime hours during a 24-hour period, creating a sound level of 100 dB for 30 seconds. During the remaining 23 hours 59 minutes and 30 seconds of the day, the ambient sound level

Figure E-7

Relationship Between Annoyance and Day-Night Average Sound Level



DNL (dB)	Percent Highly Annoyed USAF	Percent Highly Annoyed Schultz
40	0.41	0.58
45	0.83	1.11
50	1.66	2.12
55	3.31	4.03
60	6.48	7.52
65	12.29	13.59
70	22.10	23.33
75	36.47	37.05
80	53.74	53.25
85	70.16	68.78
90	82.64	81.00

Source: Federal Interagency Committee on Noise (FICON), "*Federal Agency Review of Selected Airport Noise Analysis Issues*", August 1992, p. 3-6, Figure 3.1

is 50 dB. The DNL for this 24-hour period is 65.5 dB. As a second example, assume that 10 such 30-second overflights occur in daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes of the day. The DNL for this 24-hour period is 75.4 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events and tends to emphasize both the sound levels and number of those events. This is the basic concept of a time-average sound metric, and, specifically, the DNL.

It is often suggested that a lower DNL, such as 60 or 55 dB, be adopted as the threshold of community noise annoyance for FAA environmental analysis documents. While there is no technical reason why a lower level cannot be measured or calculated for comparison purposes, a DNL of 65 dB:

(1) Provides a valid basis for comparing and assessing community noise effects.

(2) Represents a noise exposure level that is normally dominated by aircraft noise and not other community or nearby highway noise sources.

(3) Reflects the FAA's threshold for grant-in-aid funding of airport noise mitigation projects.

(4) HUD also established a DNL standard of 65 dB for eligibility for federally guaranteed home loans.

Speech Interference

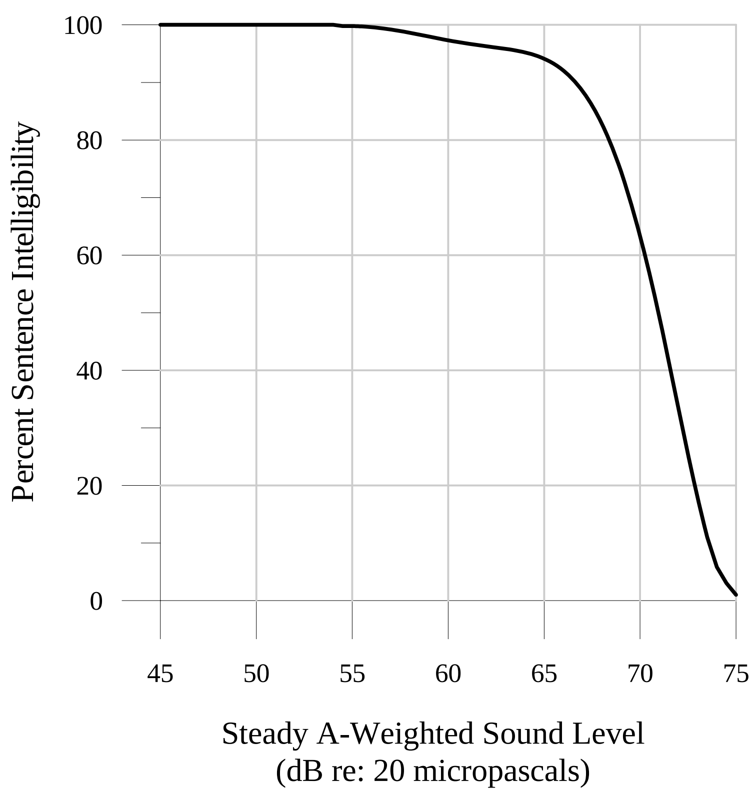
A primary effect of aircraft noise is its tendency to drown out or "mask" speech, making it difficult to carry on a normal conversation.

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities, such as radio or television listening, telephone use, or family conversation, causes frustration and aggravation. Research has shown that "whenever intrusive noise exceeds approximately 60 dB indoors, there will be interference with speech communication."[1]

Indoor speech interference can be expressed as a percentage of sentence intelligibility among two people speaking in relaxed conversation approximately one meter apart in a typical living room or bedroom.[1] The percentage of sentence intelligibility is a non-linear function of the (steady) indoor background sound level, as shown in **Figure E-8**. This curve was digitized and curve-fitted for the purposes of this document. Such a curve-fit yields 100 percent sentence intelligibility for background levels below 57 dB and yields less than 10 percent intelligibility for background levels above 73 dB. Note that the function is especially sensitive to changes in sound level between 65 dB and 75 dB. As an example of the sensitivity, a 1 dB increase in background sound level from 70 dB to 71 dB yields a 14 percent decrease in sentence intelligibility.

Figure E-8

Percent Sentence Intelligibility



Source: EPA 1974

In the same document from which Figure E-8 was taken, the EPA established an indoor criterion of 45 dB DNL as requisite to protect against speech interference indoors

Sleep Disturbance

Sleep disturbance is another source of annoyance associated with aircraft noise. This is especially true because of the intermittent nature and content of aircraft noise, which is more disturbing than continuous noise of equal energy and neutral meaning.

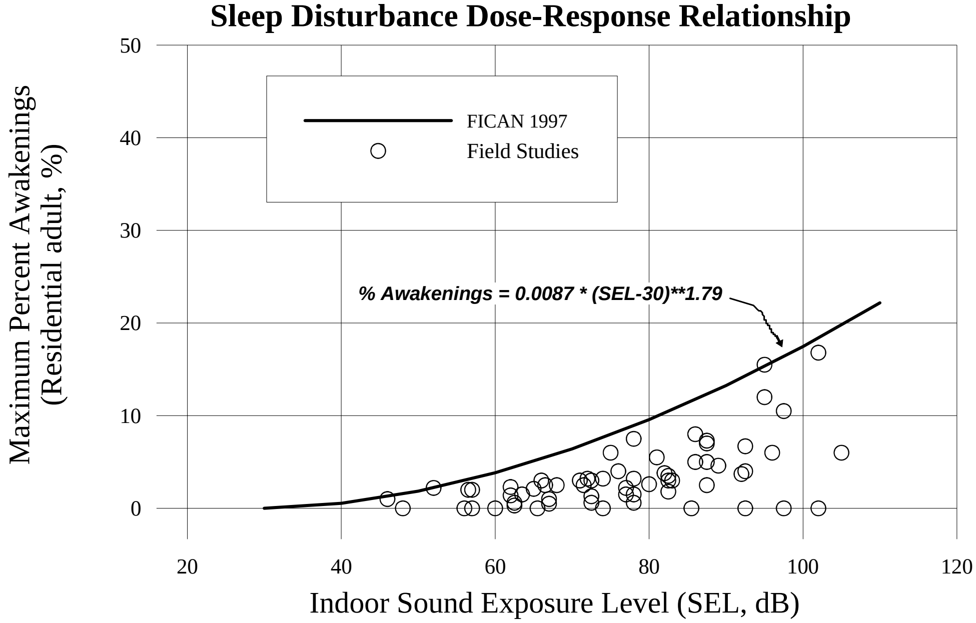
Sleep disturbance can be measured in one of two ways. “Arousal” represents awakening from sleep, while a change in “sleep stage” represents a shift from one of four sleep stages to another stage of lighter sleep without awakening. In general, arousal requires a higher noise level than does a change in sleep stage.

In terms of average daily noise levels, some guidance is available to judge sleep disturbance. The EPA identified an indoor DNL of 45 dB as necessary to protect against sleep interference.[1]

In June 1997, the Federal Interagency Committee on Aviation Noise (FICAN) reviewed the sleep disturbance issue and presented a sleep disturbance dose-response prediction curve.[12] FICAN based their curve on data from field studies[13 14 15 16] and recommends the curve as the tool for analysis of potential sleep disturbance for residential areas. **Figure E-9** shows this curve which, for an indoor SEL of 60 dB, predicts that a maximum of approximately 5 percent of the residential population exposed are expected to be behaviorally awakened. FICAN cautions that this curve should only be applied to long-term adult residents.

Figure E-9

Sleep Disturbance Dose-Response Relationship



Source: FICAN, 1997

Notes

[1] U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety," Report 550/9-74-004, March 1974.

[2] "Guidelines for Considering Noise in Land Use Planning and Control," Federal Interagency Committee on Urban Noise (FICUN), June 1980.

[3] "Federal Agency Review of Selected Airport Noise Analysis Issues," Federal Interagency Committee on Noise (FICON), August 1992.

[4] 14 CFR Part 150, Amendment 150-3 December 8, 1995

[5] FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, Department of Transportation, Federal Aviation Administration, June 8, 2004.

[6] "Sound Level Descriptors for Determination of Compatible Land Use," American National Standards Institute Standard ANSI S3.23-1980."

[7] "Quantities and Procedures for Description and Measurement of Environmental Sound, Part I," American National Standards Institute Standard ANSI S21.9-1988

[8] Schultz, T.J., "Synthesis of Social Surveys on Noise Annoyance," J. Acoust. Soc. Am., 64, 377-405, August 1978.

[9] Fidell, S., Barger, D.S., Schultz, T.J., "Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise." J. Acoust. Soc. Am., 89, 221-233, January 1991

[10] "Community Reactions to Helicopter Noise: Results from an Experimental Study," J. Acoust. Soc. Am., 479-492, August 1987.

[11] Finegold, L.S., C.S. Harris, H.E. VonGierke., "Applied Acoustical Report: Criteria for Assessment of Noise Impacts on People." J. Acoust. Soc. Am., June 1992.

[12] Federal Interagency Committee on Aviation Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997.

[13] Pearson, K.S., Barber, D.S., Tabachnick, B.G., "Analyses of the Predictability of Noise-Induced Sleep Disturbance," USAF Report HSD-TR-89-029, October 1989.

[14] Ollerhead, J.B., Jones, C.J., Cadous, R.E., Woodley, A., Atkinson, B.J., Horne, J.A., Pankhurst, F., Reyner, L, Hume, K.I., Van, F., Watson, A., Diamond, I.D., Egger, P., Holmes, D., McKean, J., "Report of a Field Study of Aircraft Noise and Sleep Disturbance." London Department of Safety, Environment, and Engineering, 1992.

[15] Fidell, S., Pearsons, K., Howe, R., Tabachnick, B., Silvati, L., Barber, D.S. "Noise-Induced Sleep Disturbance in Residential Settings," AL/OE-TR-1994-0131, Wright Patterson AFB, OH, Armstrong Laboratory, Occupational and Environmental Health Division, 1994.

[16] Fidell, S., Howe, R., Tabachnick, B., Pearsons, K., Sneddon, M., "Noise-Induced Sleep Disturbance in Residences Near Two Civil Airports," Langley Research Center, 1995.

E.2

Noise Modeling Technical Report

September 2005

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Attachments

NOISE MODELING TECHNICAL REPORT

This report provides detailed information related to the noise results disclosed in **Chapter 3, Affected Environment** and **Chapter 4, Environmental Consequences;** the methodology used in preparing the noise analysis; statistical information used in the development of the predicted noise levels; and information related to the impact of noise on people located within the Study Area. The organization of this document focuses on key assumptions and constraints affecting the overall noise analysis, the noise modeling process, and the noise metric results.

1. KEY ASSUMPTIONS AND CONSTRAINTS

A critical aspect of the NY/NJ/PHL airspace redesign noise modeling process was the integration of the delay, travel time, and airspace route data to account for noise exposure thoughout the system, as well as any changes in noise exposure based on proposed alternatives. For this analysis, the following were key modeling assumptions and constraints prior to developing the model input data:

- Modeled conditions for all scenarios must reflect the concept of an "average annual day" (AAD). As defined in FAR Part 150, data collected for noise modeling input that reflect airport activity and operational data must indicate, on an annual average-daily basis, "the number of aircraft, by type of aircraft, which utilize each flight track, in both standard daytime (0700-2200 hours local) and nighttime (2200-0700 hours local) periods of both landings and takeoffs."[1/] The AAD provides the best representation of the typical long-term (365 days) average conditions for each airport or airspace system. The condition is defined by the number and type of operations, routing structure, runway use, aircraft weight, and weather. All scenarios must be modeled using a yearly average to insure an unbiased comparison among alternatives.

- The flight schedules developed and used for both the Total Airport and Airspace Model (TAAM) and the Noise Integrated Routing System (NIRS) analysis maintained the same percentage of operations and fleet mix. The NIRS schedules reflected an average annual day condition that involve only Instrument Flight Rules (IFR) planned flights that may include overflights as well as representative military flights.

- The Baseline Conditions flight schedule was based on actual 2000 operation data collected via Enhanced Traffic Management System (ETMS) data, Official Airline Guide schedule data, Collection and Analysis of Terminal Records system (CATER) data, local radar data, and other supplemental sources of data.

- For Existing Conditions (2000), runway use and day/night distribution for the NIRS modeling were provided by actual operations data from radar data collected by airports

[1/] *Federal Aviation Regulation Part 150.* Sec. A150.103(b). Federal Aviation Administration.

with airport noise monitoring systems and ETMS data for other airports. The Future No Action Airspace Alternative scenario runway use component relied upon similar percentages based on the Existing Conditions data. The day/night distribution calculations for the Future No Action Airspace Alternative scenarios were generally based on the forecast flight schedules developed in the operational forecasting analysis (see Appendix B, Aviation Demand Forecasts). These schedules were then evaluated based on the TAAM simulation output to determine if any operational delays would accumulate and cause flights to shift into the nighttime hours. Similarly, the TAAM output stream provided the runway use and day/night distribution for future-year Alternative scenarios.

- The study area boundaries within which noise modeling was conducted were defined by a complex polygon encompassing the region. Figure 1 illustrates the Study Area used for the noise analysis. These boundaries determined the extent of the population data that was extracted from the 2000 U.S. Census data, as well as the extent of modeled flight track definitions. A maximum altitude of 14,000 feet MSL bounded the study area, based on FAA policy to model traffic to 10,000 feet AGL as indicated in FAA Order 1050.1E and the fact that the highest point in the study area is at 4,000 feet MSL (Hunter Mountain within the Catskills located in the northeast quadrant of the study area). The location for the study "center" reference point was LaGuardia Airport (KLGA) airport reference point with an altitude of 22.0 feet MSL.

- The TAAM analysis evaluated the four primary operating airspace configurations in the area; however, that do not account for a full annual average day condition at all 21 airports in the study. Additional information regarding traffic streams to and from specific runways was developed for each airport in order to adequately cover the average annual day condition.

2. NOISE ANALYSIS OBJECTIVES

Modeling the airspace in the NY/NJ/PHL area required the model to take into accounti the numerous operating configurations; the number and proximity of airports; the multiple layers of controlled airspace involving two TRACON facilities, one military facility, one Air Route Traffic Control Center (ARTCC); and the complex interaction among the traffic flows that enter and exit the airspace. Due to the size of the study area, number of aircraft entering and exiting the NY/NJ/PHL airspace, and the numerous runway use patterns, it was necessary to model several thousand NIRS flight tracks within the study area. The objectives of the noise analysis are discussed below. The process of meeting the following objectives is discussed in **Section 4** of this document.

2.1 Noise Model

For purposes of this study, a noise analysis of the entire NY/NJ/PHL airspace was considered appropriate. Due to the expected size and complexity of the study, the FAA-approved regional noise model, the Noise Integrated Routing System (NIRS) is being utilized in modeling cumulative noise exposure. The NIRS model is described in detail in **Section 4**.

The FAA's NIRS model provides a detailed tool to evaluate the effects of high-altitude and regional airspace changes from the ground level up to the maximum study altitude on noise-sensitive areas. Information to be disclosed in the Environmental Impact Statement (EIS) include the number of people within predefined DNL noise exposure ranges, and any resulting net increases or decreases in the number of people exposed to those levels of noise for the various airspace scenarios.

2.2 Compute Average 24-hour Noise Levels

For each of the noise modeling scenarios, the yearly average day/night sound level (DNL) metric levels were calculated for each of the population locations (centroids) within the study area. These points were based on 2000 U.S. Census data. Each input file contained specific airport operations categorized by runway, operation mode, and day/night. Total exposure for each input file at each centroid location was calculated. Using exposure levels from each file, the noise levels are annualized (log-added) at each centroid, which results in an annualized DNL level.

Additional noise-exposure calculations were performed for locations in noise-sensitive areas, including DOT Sec303/4f sites. These areas were covered either by individual or regularly-spaced arrays of grid points in the sensitive areas. The noise exposure in these areas was determined in the same manner as for population locations. The grid points served primarily as indicators of noise exposure at locations that do not have nearby population locations in the 2000 U.S. Census data. See **Section 3.3.11** for definition of the grids that were used for this analysis.

DNL Noise Metric

For aviation noise analysis, FAA requires that the 24-hour cumulative noise energy exposure of individuals to noise resulting from the operation of airports be established in terms of yearly day/night average sound level (DNL) as stated in FAA Order 1050.1E, "Policies and Procedures for Considering Environmental Impacts," and 5050.4A, "Airport Environmental Handbook." Therefore, the DNL metric is the primary noise descriptor for this EIS.

The DNL metric averages the total amount of noise energy produced in a 24-hour period. However, to account for the greater annoyance caused by a noise event at night (when people are trying to sleep and ambient noise levels are lower), the DNL metric imposes a penalty for nighttime noise. This is accomplished by requireing that the sound levels occurring between 10:00 p.m. and 7:00 a.m. (nighttime) be augmented by 10 dB. Essentially, the 10 dB weighting equates one night flight to ten day flights by the same aircraft. The DNL levels are calculated by adding the computed Sound Exposure Levels (SELs) of individual aircraft operations that affect a given location during a 24-hour period and weighting nighttime events by 10 dB.

2.3 Model All Typical Traffic Routes Over Entire Study Area

In order to meet the AAD requirements, all significant routes that can occur over a year were identified and modeled. Radar flight tracks were used to evaluate and model typical flight routes and flows throughout the NY/NJ/PHL airspace. All developed routes originated from actual real-time data provided by both Automated Radar Terminal System (ARTS) data and ETMS for

2000 Existing Conditions. In order to provide a system-wide source, the ARTS and ETMS data were merged together using key identifing characters (i.e., flight number and aircraft type) and geographic location. For some airports, ETMS data was the only available source used to identify traffic and runway use patterns. For the Future No Action Airspace Alternative conditions, the 2000 ARTS and ETMS data was combined with a sample of 2002 ETMS data and TAAM output to develop the modeled flight routes. For the future proposed alternatives, the TAAM airspace analysis in conjunction with additional configuration information provided by the airspace designers was utilized to make necessary adjustments to the No Action routes to reflect the alternative design.

2.4 Model Standard Aircraft Procedure Profiles with ATC Altitude Control Points

Aircraft within the study area operate in accordance with standard air traffic control procedures. To model traffic in existing and alternative airspace scenarios, NIRS arrival and departure profiles:

a. **Met specific altitude restrictions above 3,000 feet AGL as set by air traffic control, and**

b. **Used standard procedure profile data provided by NIRS (based on the FAA's Integrated Noise Model) below 3,000 feet AGL.**

The use of standard procedures below 3,000 feet AGL is required by FAA's Office of Environment and Energy (AEE). Related to the Existing Conditions analysis and Future No Action Airspace Alternative, all altitude restrictions set by air traffic control were incorporated in the NIRS analysis based upon the NY/NJ and PHL TRACON Standard Operating Procedures Manual and actual radar data. The TAAM simulation results were used for future alternatives. See **Section 3.3.9**, "**Aircraft Climb/Descent Profiles**," for further details.

2.5 Evaluation of Noise Level Changes Due to Alternative Scenarios

Airspace scenarios consist of one baseline scenario for current conditions, four scenarios for No Action and Alternative airspace conditions in 2006, and five scenarios for No Action and Alternative airspace conditions in 2011. This gives a total of ten data sets that will be modeled for noise impacts, as follows:

- 2000 Baseline Conditions – existing airspace and routes
- Interim 2006 No Action – projected 2006 airspace and routes without redesign
- Interim 2006 Modifications to Existing Airspace Alternative
- Interim 2006 Ocean Routing Alternative
- Interim 2006 Integrated Airspace without ICC Alternative
- Future Year 2011 No Action – projected 2011 airspace and routes without redesign

- Future Year 2011 Modifications to Existing Airspace Alternative
- Future Year 2011 Ocean Routing Alternative
- Future Year 2011 Integrated Airspace without ICC Alternative
- Future Year 2011 Integrated Airspace with ICC Alternative

The year 2000 is used as a baseline for this analysis for several reasons. At the onset of this study, 2000 was the most recently complete calendar year for which air traffic statistics were available. Although a study of this scope and magnitude takes a number of years to fully develop, the noise modeling of future conditions and final alternatives is based on the input data developed from the baseline conditions (2000). Thus, continual revisions of the baseline year would make it impossible to finalize the noise modeling for the study. Finally, 2000 was the last full robust year of air traffic activity prior to the aviation slowdown resulting from terrorist activities and economic down turns. Consequently, 2000 remains the best year that represents traffic levels that are similar to those being experienced currently in 2005.

As required by FAA Order 1050.1E, the difference in DNL between the Future No Action Airspace Alternative and a proposed future Alternative defines the term “change” in this analysis. The method used to identify change and the degree or threshold of such change is described in **Section 3.2.6**.

2.6 Identify and Quantify Noise Impact Changes and Causes

The change in DNL at each location between Future No Action Airspace Alternative and the proposed alternative airspace scenarios was quantified and reported for each population centroid location. In areas where any substantive changes in noise exposure occur, an analysis was conducted in order to provide a more detailed explanation of the changes. FAA criteria for substantive changes are defined in **Section 3.2.6**.

2.7 Produce Easily Interpreted, Informative Tables and Graphics to Report Results

The complexity (number of flight routes, configurations, airports, operations, etc.) of the study creates challenges in reporting noise-modeling results in a useful format for analysis. The tables and graphics presented in this appendix, as well as the main body of the EIS document were designed to summarize the data in an easily understandable format.

2.8 Noise Modeling Quality Control

The data used to model noise impacts were subjected to a series of consistency checks to maintain the consistency of data across airspace scenarios and constituent configurations. The first check involved a quality assurance analysis of the TAAM airspace modeling output. An airspace model philosophy hinges upon the concept of time and/or efficiency. Routes are usually defined over a single path that often does not represent detailed actual conditions, but meets the need to direct aircraft in and out of the airspace along key points of the route. Noise modeling philosophy focuses more heavily on precise locations and altitudes to ensure noise exposure calculations on the ground are reasonably accurate and precise. In order to ensure that the No

Action conditions were modeled accurately and that each alternative was interpreted appropriately and modeled accurately, a collaborative review effort was undertaken. This process involved integrating the operational modeling (TAAM) output, the No Action NIRS flight tracks and profiles, and the airspace alternative design documentation to evaluate each of the differences between the alternative TAAM and the No Action NIRS routes. The FAA's Design Team, the operational simulation modelers and the noise analysts reviewed each alternative on an airport-by-airport, route-by-route, and sometimes even a flight track-by-flight track basis. The result was an agreement on the fundamentals of the Future No Action Airspace Alternative airspace along with the design elements of each alternative.

Other elements of consistency checks involved NIRS input development. Flight routes and the corresponding profiles were evaluated to assure that dispersion and altitude profile calculations were made accurately, as well as for general operational appearance. NIRS output quality assurance checks included operation levels throughput to insure all operations entered into the model are accounted for in the output. Other key elements such as runway use and day/night distribution were also verified. Finally, in addition to the population centroids, noise levels were also computed at some 92,000+ grid points throughout the Study Area. These points included densly spaced points near the major airport, as well as evenly distributed points throughout the study area. The noise results and noise changes at these grid locations provided a means of investigating anomalous results and assisted in the quality control of the final noise modeling.

3. NOISE MODELING METHODOLOGY

In order to adequately inform concerned parties and decision makers it is necessary to evaluate the expected noise levels for future conditions. Since future noise levels cannot be directly measured, it is necessary to simulate the expected future condition through noise modeling. Furthermore, noise modeling is the only way that various alternative airspace designs can be compared to one another to identify the relative noise effects for each proposal.

The noise modeling effort undertaken for this EIS was developed with unprecedented care and to an extraordinary level of detail. In order to ensure that the estimations of future noise conditions presented in this document represent the best possible results, the noise modeling input assumptions were refined to a level of detail well beyond that of any previous study of this kind.

The following sub-sections describe the model to be used in the analysis, the data required for input into the model, noise model development procedures, and the output formats from the modeling process.

3.1 Noise Integrated Routing System (NIRS)

Prior to the development of the Noise Integrated Routing System (NIRS), limited technology was available to examine noise impacts associated with high-altitude air traffic changes. The FAA-accepted methodology to examine high altitude noise impacts was published in FAA Notice 7210.360, "Noise Screening for Certain Air Traffic Actions Above 3,000 Feet AGL," on September 14, 1990. The process outlined in this notice provided guidance to the development of